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Improved Staging of Liver Tumors Using Laparoscopic Intraoperative Ultrasound

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Background: Intraoperative ultrasound has been shown to provide significant assistance in operative staging and management of patients with liver tumors during open surgery. The availability of the 5.0–7.5 Mhz semiflexible ultrasound transducer with gray-scale, color and spectral Doppler capabilities can provide similar information laparoscopically.

Methods: Twenty-four consecutive patients with liver tumors (18 metastatic and six primary), in technically resectable locations determined by a variety of conventional imaging studies, were brought to the operating room. There was no known extrahepatic disease, and there was no recurrence at the primary site in the metastatic subgroup. These patients were evaluated intraoperatively with laparoscopy and intraoperative laparoscopic ultrasound to assess resectability prior to performing a major laparotomy. Laparoscopy was successful in 23 of the patients and in 19 of 23, laparoscopic ultrasound was also employed, using the 5.0–7.5 MHz semiflexible transducer. The use of the open entry technique, selection of alternate entry sites, coupled with expertise in laparoscopic lysis of adhesions, has allowed safe laparoscopic tumor staging.

Results: The laparoscopic evaluation was aborted only once due to dense adhesions, despite the fact that 67% of the patients had undergone previous abdominal surgery. There was only one complication: bleeding from a liver biopsy in an unresectable cirrhotic patient, necessitating laparotomy. Laparoscopy and ultrasound together predicted nonresectability in six of eight unresectable patients, all of whom were spared an unnecessary laparotomy.

Conclusions: Laparoscopic ultrasonographic evaluation for the staging of liver tumors should be a prerequisite to definitive laparotomy, with the objective of avoiding unncessary surgery. J. Surg. Oncol. 64: 63–67

Key Words: liver metastasis; hepatoma; laparoscopy; ultrasound

INTRODUCTION

Laparoscopy has developed as a tool for the general surgeon since the late 1980s. The introduction of video laparoscopy and rapidly growing instrument and technologic support equipment has stimulated surgeons to use laparoscopy in many new arenas. Laparoscopic tumor staging is not a new idea, but has had limited applications in the past. There is little need for the time and expense of laparoscopy if the patient's disease requires an open exploration regardless of the laparoscopic findings. The external examination of the surface of abdominal organs laparoscopically may certainly overlook lesions within

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solid organ parenchyma. The evaluation of lymph nodes laparoscopically is technically difficult, as is separating loops of bowel for a thorough and definitive examination. Laparoscopic ultrasound was considered as early as 1958 with little progress until the recent explosion of technology [1,2]. Intraoperative, nonlaparoscopic ultrasound has been shown to provide high resolution visualization, giving information that can alter the original operative plan 33% of the time during liver surgery for tumors [3]. The currently available laparoscopic ultrasound probes have given another tool to add to laparoscopic visualization of tumors. This is particularly helpful in the evaluation of solid organ tumors such as the liver [4,5]. In an effort to evaluate laparoscopy and laparoscopic ultrasound as staging tools, we evaluated 24 consecutive patients who were deemed potentially resectable by preoperative studies, including ultrasound, contrast-enhanced computed tomography, magnetic resonance imaging, computed portography with angiography, and delayed (six hours) computed portography. Because a large percentage of patients with hepatic tumors are thought to be unresectable until they undergo a laparotomy, we felt that laparoscopy and laparoscopic ultrasound could identify a subgroup of unresectable patients that would be saved the morbidity of a major laparotomy incision.

MATERIALS AND METHODS

Between August of 1993 and April of 1995, 24 consecutive patients with hepatic masses were taken to the operating room with the intent of a curative resection. Eight women and 16 men, ages 34–75 years (mean age 62.7 years) comprised the group. The pathology included 15 metastatic colorectal cancers, six primary hepatocellular carcinomas, a metastatic carcinoid, a metastatic cancer of the breast, and one of the prostate. One patient with metastatic colorectal cancer was operated a second time for a liver recurrence. Sixteen patients (67%) had previously undergone an abdominal operation. Laparoscopic exploration was successfully performed on all of the virgin abdomens and on 93% of the patients with previous abdominal surgery. In only one patient with extremely dense right upper quadrant adhesions following sigmoid resection were we not able to complete laparoscopy. Intraoperative laparoscopic ultrasound was performed on 19 of these 23 patients. Two patients had obvious extrahepatic extension found on laparoscopy alone, making ultrasound unnecessary. Scheduling problems precluded intraoperative laparoscopic ultrasound in two other patients, and open intraoperative ultrasound was used instead. General endotracheal anesthesia was used in all cases. The patients were prepared in the operating room for liver resection. The placement of invasive monitoring devices was often added after the decision to proceed with resection was made based on the laparoscopic findings.

The open laparoscopic entry technique was used in all cases. The laparoscopic ultrasound probe required a 10 mm port as did the laparoscope. This evaluation required a minimum number of two 10 mm ports. A third port was necessary if adhesiolysis was performed or for cautery of the liver surface after biopsy. Most often the entry was at the umbilical area. In the virgin abdomen, a vertical intraumbilical incision was used. In patients with previous midline incisions, a portion of the periumbilical scar was excised or incised. In both cases the abdomen was entered under direct vision. The 10 mm blunt abdominal trocar was secured to the fascia with holding sutures. If there was extremely dense adhesions in this region, precluding blunt abdominal trocar placement, insufflation, or adequate visualization, a second 10 mm blunt trocar was placed by open technique within the subcostal outline that we use for our liver resections. After adequate CO_2 insufflation, the midline umbilical region could be visualized. A 5 mm port along the costal margin outline was then placed as well to introduce scissors with cautery capability to lyse any obstructing adhesions. Once the infraumbilical area is cleared, the umbilical port can be utilized. Alternate sites for the first blunt trocar placement can be anywhere in the right midabdomen, but thought must be given to accessibility of both sides of the liver via the ultrasound probe at the time of port placement to keep the total number of ports to a minimum (Fig. 1). Using these various options for trocar placement and lysis of adhesions, we were able to adequately expose the liver and peritoneal surfaces for laparoscopic and laparoscopic ultrasound evaluation in all but one patient.

The semiflexible laparoscopic ultrasound probe (Flextip, Bruel & Kjaer Medical Systems, Marlborough, MA) is 9.6 mm in diameter and 35 cm long (Fig. 2). The probe is a multifrequency (5.0, 6.5, and 7.5 MHz) convex array transducer. The scanning end of the probe has a range of 90° up and 90° down from the horizontal plane. This is easily controlled by the operator from the probe handle. The ultrasound probe has real-time gray scale ultrasound, as well as Doppler capabilities. The probe is sterilized by immersion in Cidex (Johnson & Johnson Medical, Arlington, TX) for 30 mintues and then rinsed with sterile saline. Ten millimeters of sterile saline is placed in the probe's tip cover and secured with a silk tie. The probe can then be advanced into either of the 10 mm ports to achieve complete visualization of the liver and hilar structures. The scanning and ultrasound interpretation were done by the radiologist in the operating room. The liver is systematically scanned from right to left, examining all segments. The hepatic veins are traced from the diaphragmatic confluence inferiorly. Similarly, the portal vein is traced out to its peripheral branches. The inferior vena cava is carefully examined as well. Tumor encroachment on the central portions of these vascular structures makes the patient unresectable. The original

Fig. 1. Incision options for open diagnostic laparoscopy in the previously operated abdomen, with consideration of access to the liver for intraoperative laparoscopic ultrasound. In this instance, right upper quadrant entry was chosen because of the obvious periumbilical incisions.

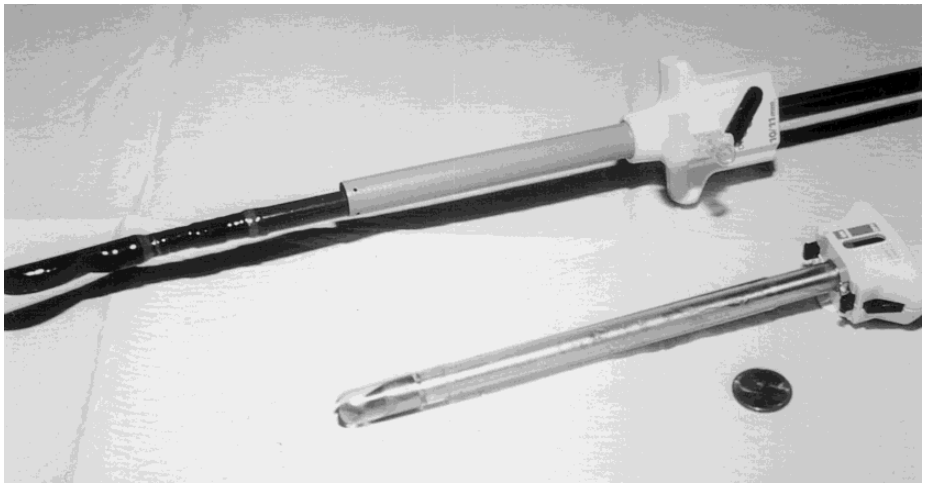

Fig. 2. The semiflexible laparoscopic ultrasound probe is easily placed through a 10 mm laparoscopic port. Size is shown in relation to that of a penny (diameter 20 mm.).

lesion(s) are identified and any newly discovered lesions are assessed with either aspiration or biopsy as needed to determine resectability. The average scanning time was 15 minutes for complete liver evaluation. The time was longer if guided biopsy procedures were necessary. The charges for the ultrasound examination were $500., one-half for performance of the study and one-half for the interpretation by the radiologist. The surgical team became adept at scanning the liver as well throughout this study.

Peritoneal studding was sampled using scissors and cautery. Intraparenchymal lesions and hilar lymph nodes were sampled with ultrasound guidance when the lesions were not visually apparent. Biopsies were obtained using the ASAP automatic 18-gauge core biopsy system (Microvasive, Watertown, MA) inserted through a separate stab wound directly over the lesion.

RESULTS

We evaluated separately the ability of laparoscopy and laparoscopy combined with laparoscopic ultrasound to determine resectability or significantly alter the operative approach. Laparoscopy alone identified 19 of 23 patients as resectable and four patients as unresectable. All 13 successfully resected patients were felt operable by lap-

TABLE I. Laparoscopy vs. Operative Findings in Patients Undergoing Liver Resection for Malignant Disease

		Operative and/or biopsy findings	
Laparoscopic evaluation		Resectable	Unresectable
Resectable	19	13	6
Unresectable	4	0	4[a]
Total	23	13	10

[a]Three-fourths did not need operative exploration because of definitive laparoscopy findings.
Only one required exploration to control bleeding.

TABLE II. Formulation of Sensitivity, Specificity, and Positive Predictive Value* in Patients Undergoing Laparoscopy and Laparoscopic Ultrasonography in Staging Patients With Hepatic Tumors

Test result	Operative and/or biopy findings	
(laparoscopy or laparoscopic ultrasound)		
Resectable (a + b)	Resectable (a)	Not resectable (b)
Unresectable (c + d)	Resectable (c)	Not resectable (d)
Total	(a + b)	(b + d)

*Sensitivity = a/(a + c); specificity = d/(b + d); positive predictive value = a/(a + b).

TABLE III. Laparoscopic Ultrasound vs. Operative Findings in Patients Undergoing Staging for Liver Tumors

		Operative and/or biopsy findings	
Laparoscopic ultrasound		Resectable	Unresectable
Resectable	13	11	2
Unresectable	6	0	6
Total	19	11	8

aroscopy, but only four of 10 unresectable patients were identified by this method alone (Table I). The 100% sensitivity is offset by a specificity of only 40%. The positive predictive value is 68% (Table II). Specificity is the critical parameter as it is this parameter that saves patients from needless laparotomy.

In the 19 patients who had the benefit of laparoscopic ultrasound added to the laparoscopy, the results were much better. Eleven of 13 patients deemed resectable by laparoscopic ultasound were in fact resectable (positive predictive value of 85%). Again, the sensitivity is 100% (11/11). More importantly, six of eight unresectable patients were identified by laparoscopic ultrasound (specificity of 75%), saving them from a needless exploration (Table III).

Of the 23 patients undergoing successful laparoscopy, evaluating this modality without the addition of laparoscopic ultrasound evaluation, three of 10 unresectable patients were saved a laparotomy incision. In eight patients, laparoscopy simply verified preoperative findings and the procedure went on as planned. However, in 10 of the remaining 15 patients (66%), significant changes were made in the operative strategy that were not detected by simple laparoscopy alone. Such changes usually consisted of extending the resection because of the discovery of additional malignant lesions or deciding on nonresectability because of universal multilobed disease.

Intraoperative laparoscopic ultrasound saved unnecessary laparotomy in six of eight patients (75%) found unresectable. In four patients, intraoperative laparoscopic ultrasound verified the preoperative studies, and the planned resection was performed without modification (26%). In 13 of the remaining 15 patients (86%), the plan was altered by intraoperative laparoscopic ultrasound and laparoscopic findings viewed together. In 11 of 15 patients (73%), the preoperative plan was changed based solely on intraoperative laparoscopic ultrasound findings. Two patients (10%) had findings missed on both laparoscopy and laparoscopic ultrasound that precluded resection which were diagnosed at laparotomy.

Table IV outlines the preoperative studies contrasted with the operative diagnostic findings and resectability rate. Considered together, laparoscopy and intraoperative laparoscopic ultrasonography saved needless laparotomy incisions in seven of 11 patients (64%) found unresectable.

DISCUSSION

The major point to be emphasized in this experience is that patients with unresectable lesions were spared a laparotomy incision 64% of the time by a combined application of laparoscopy and laparoscopic ultrasonography. Laparoscopy and intraoperative ultrasound together can be performed safely in patients who have had previous abdominal operations. In only one patient were we unable to perform adhesiolysis to visualize the liver. In only one patient was there morbidity requiring laparotomy incidental to a laparoscopic biopsy in a cirrhotic liver requiring hemorrhage control. This biopsy had in fact proved the patient to be unresectable.

Intraoperative laparoscopic ultrasound is an important addition to laparoscopy in staging hepatic tumors. The planned course of therapy was altered 33% of the time if laparoscopy alone was used, but 86% of the time when laparoscopy was enhanced by intraoperative laparoscopic ultrasonography. Whereas laparoscopy alone was disappointing in its ability to significantly alter the operative approach, when combined with laparoscopic ultrasound it becomes a powerful tool in staging hepatic tumors. The ultrasound scanning and interpretation, as well as the equipment for the scanning, were provided by radiology in this study at minimal cost to the patient. The accomplished laparoscopic liver surgeon can easily learn to scan the liver and interpret the anatomic findings. Learning the technique for ultrasound-guided laparoscopic bi-

TABLE IV. Preoperative Studies and Operative Findings in Liver Tumors*

Patient	CT[a]	Us[b]	MRI[c]	Agram[d]	CATP[e]	Scope	LAP Us[f]	LAP[g]
1	R					R	ND	R
2	?R					NR	ND	ND
3	R			R	R	R	R[h]	R
4	R		R	R	?NR	R	NR	ND
5	R			R	R	R	R	R
6	R			R	R	R	R[h]	R
7	?R					NR	NR	ND
8	R					INC	ND	NR
9	R		R			R	NR	ND
10	R			R	R	R	R	NR
11	R					R	ND	R
12	R			R	R	R	R	R
13	R			?NR	?NR	R	NR	ND
14	R		R			R	R	R
15	R		R			R	NR	ND
16	R			R	R	R	R	R
17	R		R			R	R[h]	R
18	R			R	R	R	R[h]	R
19	R					R	R[h]	R
20	R			R	R	NR	NR	ND
21	R					R	R	R
22	R	R	R			NR	NR	ND
23	R			R	R	R	R	R
24			R	R	R	R	R	R

*INC = incomplete, R = resectable, NR = not resectable, ND = not done.
[a]Contrast-enhanced computed tomography.
[b]Ultrasound.
[c]Magnetic Resonance Imaging.
[d]Arteriogram.
[e]Computed protography with angiography.
[f]Laparoscopy.
[g]Laparotomy.
[h]Changed operative plan of resection.

opsy is somewhat more difficult laparoscopically, but readily attainable after several cases. The laparoscopic evaluation can be accomplished within 20–40 minutes, ultrasound scanning within 15 minutes, and each biopsy in ~20 minutes. These same maneuvers would still be performed in open cases to determine resectability; therefore, little additional anesthesia time is actually being expended.

In summary, laparoscopy and intraoperative laparoscopic ultrasound are safe and in our opinion a necessary prerequisite in operations for primary or metastatic liver tumors. They should be prospectively analyzed against other modalities of cross-sectional imaging and particularly computed portography in order to reach the ideal algorithm for the evaluation and staging of hepatic lesions.

REFERENCES

1. Frank K, Bliesze H, Honhof JA, et al.: Laparoscopic sonography: a new approach to intraabdominal disease. J Clin Ultrasound 1985;13(1):60.
2. Goldberg BB, Liu JB, Merton DA, et al.: Sonographically guided laparoscopy and mediastinoscopy using miniature catheter-based transducers. J Ultrasound in Med 1993;12(1):49–54.
3. Rifkin MD, Rosato FE, Branch HM, Foster J, et al.: Intraoperative ultrasound of the liver, an important adjunctive tool for decision making in the operating room. Ann Surg 1987;205:5, 466–472.
4. John TG, Greig JD, Crosbie JL, et al.: Superior staging of liver tumors with laparoscopy and laparoscopic ultrasound. Ann Surg 1994;220(6):711–719.
5. John TG, Greig JD, Carter DC, Garden OJ: Carcinoma of the pancreatic head and periampullary region: Tumor staging with laparoscopy and laparoscopic ultrasonography. Ann Surg 1995;221:156–164.

COMMENTARY

Endoscopic Surgeons (SAGES) and the American College of Surgeons are both supportive of the use of ultrasound by surgeons and indeed are developing courses in order that surgeons learn these techniques. An additional area of interest is endoscopic ultrasonography utilizing specially designed flexible instruments which allow for the intraluminal endoscopic staging of esophageal, gastric, and colorectal carcinoma.

I salute Dr. Barbot and her colleagues for utilizing these important techniques in their approach to hepatic resection and hope that their work and interests will be emulated by others.

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